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Best Management Practices for Selected Industries and Additional Resources

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Introduction

Water consumption in the Semiconductor, Metal Plating, Printed Circuit Boards, Paper and Rubbers and Plastics industries is quite high. Knowledge of water balance for the entire facility and specifications for each stream are useful for a program on water conservation. Simple engineering systems such as countercurrent flows, high pressure low volume atomized or fog spray rinsing systems, tying dumping of baths to measurement of critical bath parameters, installing essential instrumentation (e.g. flow restrictors, conductivity controllers, pH meters, etc.) and installing filtration/screening and cooling systems provide options to reclaim, refine and reuse water continuously.

Water Conservation Plans (general)

Water is an important resource or raw material in the manufacturing of various products; however, for many facilities water is usually considered an overhead cost. In most municipalities in the Commonwealth of Massachusetts, facilities pay a contracted rate for the volume of water supplied and a sewer cost, typically at a higher and different rate. To appreciate the contribution of water to the operation of any plant, there should be a cost value assigned to its input, whether it is a reactant, a solvent, a cleaning agent, a convenient means to transport other resources, or a way to store intermediate or final products.

Controlling the use and cost of water is the responsibility of everybody in the company. A policy statement with clear objectives that is supported by top management will define the company's position on water use. The objectives serve as guidelines to develop goals that all employees can work towards. Included in this policy, a management team should be established and a continuous program for educating employees should be implemented.

The management team monitors the use of water in the facility and to formulate an equitable means of allocating cost to the use of water and its disposal. For a small facility, these responsibilities maybe assigned to an individual with the additional authority to enforce viable and cost-effective changes.

Basic Program

Outlined below are some simple, practical and general measures and procedures that may promote water conservation and optimal uses in some industry sectors. The list is by no means exhaustive. The peculiarities of an individual facility may make some of the suggestions impractical - ideally, such peculiarities should be viewed as opportunities to develop viable alternatives.

Water Balance

Measurements should be taken to establish a water balance for all operations. Inputs and effluents from all processes should be assessed. The flow of water to all points of input and effluent for all process steps should be measured, documented and continuously monitored. Water meters may be installed for major consumers. Simple methods to estimate flow rates, e.g. using a bucket and a timer, can be adequate to get reasonable flow rates. Flow rates should be determined for all flows using appropriately sized flow meters, where possible. The flow rates should be compared to plant design specifications, and used as a baseline against which the success of any water conservation scheme may be measured. Flows to plants and equipment should be kept to the rates specified by the equipment manufacturers.

Cost Centers
A realistic cost value based on volumes used should be assessed to all process steps. Major consumers may be considered cost centers and the cost to supply water and to dispose of wastewater should be documented regularly.

Monitor and Audit
At established periodic intervals, flow rates should be measured and compared with those established through the water balance.

Maintenance
All fresh water and wastewater leaks should be logged on a daily basis. Maintenance should be carried out to fix leaks within 24 hours of their discovery.

Energy Savings
In many operations, energy savings will be realized at the same time that water conservation is implemented.

Semiconductors

Water Demands
Semiconductor fabricators (fabs) use a tremendous amount of water, much of it pretreated to a desired purity. One eight-inch wafer can require up to 3,000 gallons of ultra-pure water, and in some plants, daily water use can exceed 3 million gallons.

Given the limited water supply in the I-495 area, efficiency measures could alleviate the strain on municipalities as well as increase profit and productivity for the plants themselves.

Process water use in fabs may be approximated as follows:

- 60% wet cleans
- 20% acid processes (etching)
- 10% solvent processes
- 10% tool cleaning

The facility should establish definite standards for the water used in each application strictly in line with the level of "cleanliness" demanded by the application.

Treatment of effluents from each application should include first and foremost the objective to reclaim and recycle the water for the initial application.

Opportunities to use the effluent from one process without treatment for other processes should be thoroughly investigated and implemented.

The following simplified considerations should be given to the processing of water in the semiconductor industries:

Avoid using ultra-pure process water for non-process activities. In some cases, 25-50% of the total purified water supply is used for cooling, irrigation, and sanitation. Creating DI water is among the most expensive and energy-intensive steps in the fabrication process, so any decreases in water demand can result in significant savings. Billing different departments and workgroups for actual DI water use can discourage this behavior.

Use Countercurrent Flow in the Rinsing Process. In this most water-intensive manufacturing step, eliminating unnecessary cycles and rinsing only until desired cleanliness is reached can be achieved using sensitive flow controls and monitoring equipment.

For countercurrent flow, the workpiece should travel from the dirtiest rinse tank to the cleanest or purest water tank.

The workpiece should never be dragged over the cleanest or final rinse on the way to the first stage rinsing or cleaning. Position the tanks for easy workpiece travel.

To further reduce the volume of fresh water used in the final stage, a suitable spray device that is programmed to operate only when the workpiece is within the stage should be installed.

Switching from continuous to on-demand rinsing is a relatively simple change that can result in major water savings.

Spray rinsing with low-flow and appropriate high pressure nozzles can reduce rinse-water use up to 60% compared with counter-current immersion rinsing.

Measure Important Parameters Before Dumping Water. Upper limits for relevant parameters for process water such as conductivity, total dissolved solids (TDS), pH, etc. should be established. Dumping of the water should only be carried when these parameters have been tripped or exceeded.

Dumping should not be based simply on elapsed time or frequency of use.

Recycling-Reuse
While most opportunities in this area require significant filtration/treatment equipment and re-plumbing, it is useful to understand the large potential for water savings.

Direct recycling of process wastewater back to the same application in the fabrication process can require complex filtration systems in order to achieve the needed purity. This is perhaps the most difficult of the recycling processes, though it can be made cost-effective, especially since DI water is already quite expensive to produce. A common method is to isolate the cleanest waste streams and use only those for recycling. This method will cut down on the number of contaminants that require filtration and consequently, the extent of treatment required.

In some cases, reclaimed water that does not meet purity requirements for a particular processing can be reused for other activities in the facility, for example, water for non-contact cooling, process exhaust scrubbers, irrigation, and sanitation.

Efficiency measures- "hardware"
These are changes in process machinery and tooling that save on water by the use of special items of equipment.

> *Flow Restrictors:* These items include a host of simple devices amongst which are general flow restrictors to limit flows to preset flow rates, spray nozzles to supply water spray of defined patterns for effective cleaning, electronic or mechanical controllers that start and stop water flows only when products are processed and spray gun attachments to manual hoses.

> *Instrumentation:* These items include such items as conductivity controllers, total dissolved solids measuring devices, pH meters or such devices that measure critical parameters that are set to initiate dumping.

> *Flow Meters:* Flow meters should be installed on the feed line to major water users. The measurements should be reviewed periodically and regularly.

> *Operation and Maintenance:* All major water consumers within the facility should be properly sized and operated at designed operating conditions. Scheduled and preventive maintenance should be promptly carried out. All leaks should be fixed within set time as they are discovered.

Efficiency Measures - "Software"

> *Education and Training:* Senior level staff should teach operators and all staff

Education and Training: Senior level staff should teach operators and all staff involved with the major water consumers about operating costs for water/sewer for each consumer. The costs should be logged periodically.

Metal Plating

Drag-out constitutes a significant volume source of wastewater generation in metal plating. By reducing the amount of drag-out solution on parts, the volume of required rinse water along with the amount of contaminants entering the next process bath will be reduced. Increasing rinse efficiency will reduce the volumes of wastewater that have to be treated and disposed of properly. Reuse and recycling of various effluents can also conserve the amount of water a metal finishing process consumes. These three areas are addressed in the following list of best management practices that can help your facility increase profits while decreasing the volume of water required to effectively run your operations.

Drag-out Reduction

Operate each bath at maximum permissible temperature to lower the bath solution's viscosity and surface tension.

Non-ionic wetting agents can be used in the process baths (but not the rinse baths) to reduce the surface tension of the solution and thereby decrease the amount of drag-out.

Several measures can be implemented to increase the amount of solution returned to the process bath prior to dipping into rinse baths:

- Withdraw pieces from the bath slowly
- Install drainage boards between process baths and rinse baths to return drag-out solutions back to the process baths
- Install rails above process baths to hang workpiece racks for drainage
- Use air knives or spray rinses above process baths to rinse excess solutions off and into the process baths

Partially immerse barrels versus the standard practice of full immersion.

Restore barrel holes.

Rack parts so the face is almost vertical and the longest dimension is horizontal, with the lowest edge tilted from the horizontal. Also, parts should not be racked directly over one another.

Rinse Systems

Use air or workpiece agitation to improve rinse efficiency.

Install multiple rinse baths, including counter current rinse baths, after process baths to improve rinse efficiency to reduce waste consumption. Counter-current rinsing with multiple tanks uses up to 90% less rinse water than a conventional single-stage rinse system.

Employ water conserving rinse methods such as fog or spray rinsing systems, reactive rinsing.

Use simple controls that conserve water including flow restrictors on flowing rinses, flow control valves automatically activated when work pieces are introduced, conductivity or other parameter controllers to determine the dumping of dead rinses, devices for agitation to assure adequate rinsing and homogeneity in rinse tank, and static drag-out rinse tanks.

Recycling & Reuse

Treating rinse water effluent before discharge to recover process bath chemicals allows for the reuse of effluent for rinsing or neutralization.

Reactive rinsing reuses the acid rinse effluent as influent for the alkaline rinse bath, allowing the fresh water supplied to the alkaline rinse tank to be shut off.

For further information:

"Pollution Prevention and Best Management Practices for Metal Finishing Facilities"
http://www.co.broward.fl.us/environment/publications.htm
Scroll down to Best Management Practices section"

Printed Circuit Boards

Water use by printed circuit boards manufacturers in the I-495 area is estimated to be about 1.5 million gallons per day. The water is used mostly for rinsing and electroplating processes. The procedures outlined earlier can be easily implemented to conserve the volume of water used in any facility.

Specifically for printed circuit board manufacture, there are a number of water-saving process changes and controls that can be inexpensively incorporated in the production process.

Use dry film photoresist instead of wet applications.

Examine the pre-plating rinsing process.

- Based on monitoring data, eliminate unnecessary cycles and rinsing only until desired cleanliness is reached. Reducing the frequency of automatic dumping by this method is an excellent start.
- Switch from continuous to on-demand rinsing, and from once- through to closed-loop use.
- Use counter-current rinsing.
- Use air or workpiece agitation to increase rinsing efficiency.
- Spray rinsing with high-pressure low-flow nozzles. This can reduce rinse-water use up to 60%.
- Link flow controls to conductivity meters that measure the total dissolved solids (TDS) in the rinses

Examine the electroplating process. Extending bath life will reduce both water consumption and toxics in the effluent.

- Reduce drag-in through efficient rinsing.
- Use DI or distilled water for make-up.
- Reduce drag-out through the following methods:
  - Minimize bath chemical concentrations.
  - Use non-ionic wetting agents to reduce surface tension in the process baths.
  - Prior to rinsing, maximize water returned to the process bath through several measures --withdraw pieces from the baths slowly, install drainage boards between process baths and rinse baths to return drag-out back to the process baths, install rails above process baths to hang workpiece racks for drainage, and/or use air knives or spray rinses above process baths to rinse excess solution off and into the process bath.
  - Restore barrel holes.
- Maintain bath solution quality through monitoring, replacement of reagents and stabilizers, and impurity removal.

Install multiple baths after the process bath for using counter-current rinsing wherever possible. All of the above pre-plating rinsing methods should also be adopted in this step.

For further information:

EPA Office of Wastewater Management:
http://www.epa.gov/owm/index.htm

http://www.epa.gov/owm/index.htm

Paper Mills

Paper mills use water as a medium to transport fibers, energy and chemicals during the production of paper. The volume of water used per ton of paper produced depends on several factors including the types of products, the equipment used, the configuration or arrangements of the equipment, the production process, the operating conditions and parameters. Water consumption in a paper mill can vary between 12 to 35 tons of water per ton of paper with a good average at about 20 tons of water per ton of paper. Water consumption tends to be quite high for mills that produce colored papers due to the necessity to discharge all whitewater after most color changes.

The recommendations made at the beginning of this presentation are particularly applicable to the industry and they should be implemented appropriately. The following additional suggestions are made to further reduce water consumption at specific locations. Implementation will require the cooperation of all mill staff (including management) and customers.

A significant reduction in fresh water consumption can be realized by optimizing the design and operation of the whitewater system in the mill. Whitewater should be the primary source of water for pulping especially when its color is compatible with the color of the paper being produced. The use of fresh water for Headbox, Breast, Knockoff, Forming Fabric, and Wire Return Roll Showers for most paper machines can be substituted with screened and clarified whitewater.

Pulper: Whitewater should be used for making stock. Whitewater from the machine room or the whitewater chest should be the first source of water for stock preparation, if the color is acceptable for the batch of paper to be produced.

Vacuum Seal Water: The temperature of effluent seal water is higher than that of the feed water. Besides the increase in temperature, the main contaminants in seal water are fiber and felt hair. There could also be some solids pick up from the felt. A cooling tower can be installed to reduce the temperature and screens and filters can be used to remove the other contaminants. The cleaned water can then be reused. It is also possible to cascade the cooler seal water effluent from the high vacuum pumps (couch, flat boxes) to the low vacuum pumps (press, felt conditioning, etc.). The hot water now generated can be stored and used for stock preparation.

Non-Contact Cooling Water: Non-contact cooling water should be collected and stored in the hot water storage tank. Water from this tank can be used for stock preparation in the pulper, preparation of additives, colors and finishing materials.

Felt Cleaning Water: Fresh water is often utilized for felt cleaning on paper machines and presses and discarded to the sewer thereafter. The used water would typically contain felt (hair) and low concentrations of fiber, color and stock additives. It is possible to separate the felt/hair component and reuse the water upstream in stock preparation.

Showers: Check to see if high-pressure, low-volume showers instead of low-pressure, high-volume showers can be used for every application. Clarified white water can be used for guide edge knock-off showers, guide showers and breast roll showers. Some guide roll showers can be connected in a sequence that allows fresh water supply to only one while the others are fed with filtered effluent from the preceding shower.

For further information:

EPA Office of Wastewater Management:
http://www.epa.gov/owm/index.htm
EPA's pilot workshop 'Identifying P2 Opportunities through Pretreatment: Program Implementation' materials, 1992.
EPA Pulp and Paper Industry Sector Notebook
http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulp
MWRA 'A Guide to Water Management: The MWRA Program for Industrial, Commercial and Institutional Water Use': 1995.
Panchapakesan, B. "Closed White Water System Designs", Environmental Issues and

Panchapakesan, B. "Closed White Water System Designs", Environmental Issues and Technology in the Pulp and Paper Industry, A TAPPI PRESS anthology of Published Papers, 1991 - 1994

Rubber and Plastics

Water demands from the rubber and plastics industries in the I-495 area approach 3.5 million gpd. Much of this is in the form of contact and non-contact cooling water, the topics on which this BMP will concentrate. The general water management procedures outlined at the beginning are also relevant for these industries.

Cooling water is generally used in three ways: in cooling towers, in circulating evaporative cooling systems, and in single-pass applications.

Cooling towers

- Minimize blowdown, automating with a conductivity monitoring system.
- Perform with chemical and non-chemical de-scaling and biological treatments, using non-toxic alternatives when possible.
- Maximize the number of cycles that water is used before bleed-off, as well as the concentration factor of the cooling tower water.

Evaporative cooling systems

- Bleed off only the necessary amount of water.
- Examine the heat transfer sites in order to ensure that the materials used are as thin as possible and have high heat conductivity.
- Make sure that water circulators exist inside the coolers in order to maximize heat transfer.
- Keep the conductive surfaces clean for optimal efficiency

Single-pass cooling

- Try to eliminate this most wasteful method of cooling. Viable alternatives include the two above, as well as circulating air-chillers.
- If once-through use cannot be avoided, examine the cooling process for unnecessary use and flow volume, reducing water use wherever possible.

For further information:

EPA Office of Wastewater Management
http://www.epa.gov/owm/index.htm
EPA's pilot workshop "Identifying P2 Opportunities through Pretreatment: Program Implementation" materials, 1992.
MWRA "A Guide to Water Management: The MWRA Program for Industrial, Commercial and Institutional Water Use": 1995.

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